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NOISE ATTENUATION PERFORMANCE OF THE JOINT SERVICE AIRCREW MASK (JASM) – JOINT STRIKE FIGHTER (JSF) WITH THE LIGHTNING II GENERATION II HELMET

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Interim Report

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14. ABSTRACT

Noise attenuation performance tests were performed on the Joint Service Aircrew Mask (JSAM)-Joint Strike Fighter (JSF) with the Lightning II Generation II (Gen II) Helmet Mounted Display (HMD) at the Air Force Research Laboratory's (AFRL) Acoustics facilities at Wright-Patterson Air Force Base March 2012. American National Standards Institute (ANSI) methods ANSI S12.6 and S12.42 were used to measure the passive attenuation and active insertion loss performance respectively. The objective of this study was to establish a baseline for the noise attenuation performance. When comparing the total attenuation of the Gen II HMD with and without the JSAM-JSF, a degradation of 3 dB or more was found at the lower frequencies (125-500 Hz) with the addition of the JSAM-JSF. This degradation was due to the reduction of active insertion loss.

15. SUBJECT TERMS
JSAM, JSF, Gen II HMD, noise attenuation, REAT, MIRE, active insertion loss

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TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

Joint Strike Fighter (JSF) aircrews don the F-35 Lightning II Generation II (Gen II) Helmet Mounted Display (HMD), a Vision Systems International (VSI) product, to combat noise in the cockpit and provide satisfactory voice communication capabilities. The Joint Service Aircrew Mask (JSAM)-JSF is worn in combination with the Gen II HMD to provide the chemical/biological (CB) protection to the respiratory system in an actual or perceived CB warfare environment. The objective of this study was to establish a baseline for the noise attenuation performance by measuring the noise attenuation of the JSAM-JSF worn in combination with the F-35 Gen II HMD. The data would be used to determine if the JSAM-JSF meets the noise attenuation requirement (Gen II HMD total noise attenuation minus 3 dB per octave band). Passive attenuation was measured using the American National Standards Institute (ANSI) Methods for Measuring the Real-Ear Attenuation (REAT) of Hearing Protectors ANSI S12.6-1997(R2002)[1], Method A while active insertion loss was measured using Microphone-in-Real-Ear (MIRE) and Acoustic Test Fixture Methods for the Measurement of Insertion Loss of Circumaural Hearing Protection Devices ANSI S12.42-1995(R2004) [2].

2.0 BACKGROUND

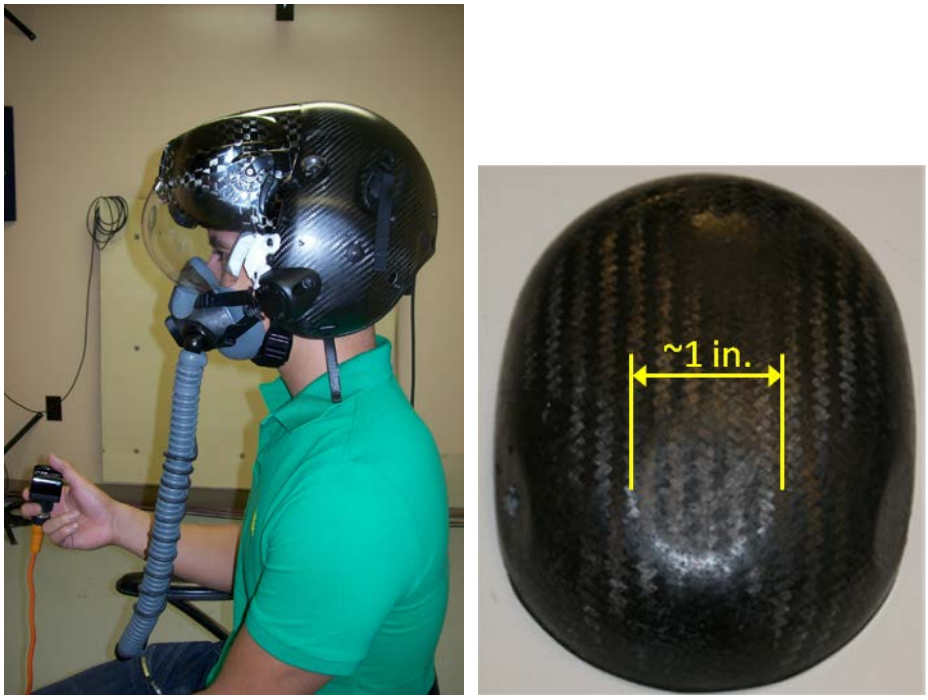
The JSAM-JSF respirator is a CB protective system which provides "above the neck" head-eye-respiratory and percutaneous protection against CB warfare agents, radiological particles, and continuous protection against CB agent permeation for both ground and in-flight operations (Figure 1). The JSAM-JSF provides the capability for aircrew to fly throughout their full operating envelope and perform their mission in a CB warfare environment.

Figure 1. JSAM-JSF CB protective respirator system

Noise attenuation performance tests on the F-35 Lightning II Gen II HMD (Figure 2a) were performed at the Air Force Research Laboratory's (AFRL), 711th Human Performance Wing, Human Effectiveness Directorate, Decision Making Division, Battlespace Acoustics Branch (711 HPW/RHCB) in 2008 and 2012. The helmet system included a Helmet Assembly Unit, fit adjustment and retention system, bi-ocular display unit (including display and external tinted visors in down position) mounted to the helmet, generic liner pads, Helmet Integrated System Ltd (HISL) active noise reduction (ANR) earcups (part number JS02591, Figure 2b), and a MBU-23/P oxygen mask with customized bayonets. This data was used to determine if JSAM-JSF was meeting the requirement where no greater degradation than 3 dB per octave band was allowable when compareing the total noise attenuation of the Gen II HMD with and without the JSAM-JSF[3]. Table 1 displays the Gen II HMD total noise attenuation minus 3 dB per octave band.

JSAM Specification Paragraph 3.4.9.3, item 71 (Reference 3)[3]:

> *The JSAM when integrated with existing head-mounted personal/life support equipment in Appendix E shall result in no more than a 3 dB degradation of the measured one-third octave band hearing attenuation compared to the original (non-JSAM) configuration.*



a. **b.**

Figure 2. a. F-35 Lightning II Gen II HMD b. Original ANR Earcups

Table 1. JSAM-JSF Requirement (baseline Gen II HMD total attenuation data collected in both 2008 and 2012 minus 3 dB)

	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
Requirement (Gen II HMD 2012 - 3 dB)	4.95	10.51	14.73	20.68	19.90	33.65	37.66
Requirement (Gen II HMD 2008 - 3 dB)	9.45	12.99	15.28	19.19	21.75	36.82	46.97

3.0 METHODS

All passive and active noise attenuation measurements were conducted at the AFRL Battlespace Acoustics Branch at Wright-Patterson Air Force Base, Ohio. Attenuation performance measurements were collected on the JSAM-JSF worn in combination with the Gen II HMD, Figure 3. Ten paid volunteer subjects participated in the measurements; 5 male and 5 female subjects ranging from 19 to 29 years of age. These were the same subjects that participated in the Gen II HMD noise attenuation measurements in 2012 with the exception of one female subject. She had to be replaced due to head size and the limited availability of assets during testing. All subjects had hearing threshold levels less than or equal to 15 dB from 125 to 8k Hz and were examined for healthy eardrums and clean ear canals. Anthropometric head and neck measurements were collected for each subject, Table 2. Table 3 lists the size of the Gen II HMD and JSAM-JSF for the participating subjects. All subjects were fit by an expert fitter from Gentex, Lockheed Martin (LM) and the JSF Program Office to ensure proper JSAM-JSF and Gen II HMD fit procedures[4]. Subjects also wore an F-35 sleeved flight jacket, with the life preserver unit (LPU) removed, to stabilize the filter blower unit.

Figure 3. Male subject seated in test facility while wearing the JSAM-JSF in combination with the Gen II HMD

Table 2. Anthropometric head and neck measurements for participating subjects

Subject	Anthropometric Head and Neck Measurements (cm)

ID	Head Circumference	Head Length	Head Width	Nasal Root to Supramentale	Neck Circumference
1487	55.8	19.0	13.9	8.7	33.0
1482	57.6	20.1	15.2	8.9	38.7
1208	56.9	19.0	14.9	10.0	38.7
1427	55.9	19.2	15.3	9.0	37.3
1438	55.9	18.9	14.9	8.8	38.5
1401	59.6	20.2	15.8	10.5	37.2
1496	55.5	18.2	14.5	7.7	34.9
1447	57.3	20.2	15.5	8.5	40.0
1481	58.4	19.6	14.8	8.0	40.5
47	58.9	21.1	15.0	8.5	42.0

Table 3. JSAM-JSF and Gen II HMD equipment list / sizes per participating subject

Subject ID	Equipment List and Size	
	Gen II HMD	**JSAM-JSF**
1487	M	DVT II
1482	M	DVT II FAST
1208	L	DVT II FAST
1427	M	DVT II FAST
1438	M	DVT II FAST
1401	L	DVT I
1496	M	DVT I
1447	M	DVT II
1481	M	DVT II FAST
47	L	DVT III

3.1 REAT

The AFRL REAT facility was used to measure the passive hearing protector performance. The facility was built for the measurement, analysis, and documentation of the sound attenuation properties of passive hearing protection devices. The chamber, its instrumentation, and measurement procedures were in accordance with ANSI S12.6-1997(R2002).[1] The 2008 version of ANSI S12.6 was not used in order to directly compare the JSAM-JSF with Gen II HMD configuration to the data collected on the Gen II HMD alone. ANSI S12.6 consisted of measuring the occluded and unoccluded hearing threshold of human subjects using a von Békésy tracking task. The thresholds were measured two times for the unoccluded condition and two times for the occluded condition. The four thresholds per subject were averaged in accordance with the standard to determine a mean attenuation value. The data from all subjects in each test condition was then averaged to determine mean and standard deviation values. Figure 4 is a side view of a male subject wearing the JSAM-JSF and Gen II HMD inside the REAT chamber.

Figure 4. Male subject in REAT chamber wearing the JSAM-JSF and Gen II HMD

3.2 MIRE

The AFRL MIRE facility was used to measure the active insertion loss of ANR hearing protectors. The facility and measurements were operated in accordance with ANSI S12.42-1995(R2004).[2] Miniature microphones, Knowles model BT-1759, were used to simultaneously measure the sound pressure levels at the entrance of both ear canals. 115 dB flat noise spectra were generated and three measurements were collected to complete one trial: open (without the hearing protector), closed (with the hearing protector) ANR off, and closed (with the hearing protector) ANR on. The ANR on condition was powered by a portable 20 volt power supply. Three trials were collected per subject according to the standard. The three trial samples of the hearing protection device were averaged for each of the subjects. Average measurements for the ten subjects were then calculated for each experiment. A test subject seated in MIRE (closed condition) is shown in Figure 5.

Figure 5. Female subject sitting in MIRE facility (occluded ear condition)

3.3 Total Attenuation Calculation

The total attenuation performance of the system was calculated by adding the mean active insertion loss data to the mean minus two standard deviation passive attenuation data. The total attenuation data would then be compared to the noise attenuation requirement, Table 1.

4.0 RESULTS

The ANSI S12.6-1997(R2002)[1] real-ear attenuation performance and ANSI S12.42-1995(R2004)[2] microphone-in-real-ear measurements of the JSAM-JSF worn in combination with the F-35 Lightning II Gen II HMD was measured at AFRL. REAT (passive attenuation), MIRE (active insertion loss), and total attenuation (passive plus active calculation) results were collected and analyzed.

4.1 REAT – Passive Attenuation

Passive attenuation performance was measured on the JSAM-JSF worn in combination with the Gen II HMD in AFRL's REAT facility. Mean and standard deviation data from 125 Hz to 8k Hz for all 10 subjects is shown numerically, Table 4, and graphically, Figures 6-7. Figure 6 compares the mean attenuation of the Gen II HMD with and without JSAM-JSF. Figure 7 compares the mean minus 2 standard deviations for the Gen II HMD with and without the JSAM-JSF.

Table 4. Mean and standard deviation passive attenuation results from REAT measurement

		Frequency (Hz)						
		125	250	500	1000	2000	4000	8000
Gen II HMD with Original Earcups (Jan 2012)	Mean	14.68	9.20	10.51	28.79	32.17	45.86	52.27
	SD	7.22	4.39	3.29	4.36	3.58	4.21	5.71
Gen II HMD with Original Earcups (2008)	Mean	15.00	9.00	11.00	27.00	33.00	47.00	56.00
	SD	5.00	3.00	3.00	4.00	3.00	3.00	3.00
Gen II HMD with JSAM-JSF	Mean	12.48	9.92	13.98	28.57	34.29	47.11	46.98
	SD	4.11	5.51	4.58	5.20	2.91	3.34	4.39

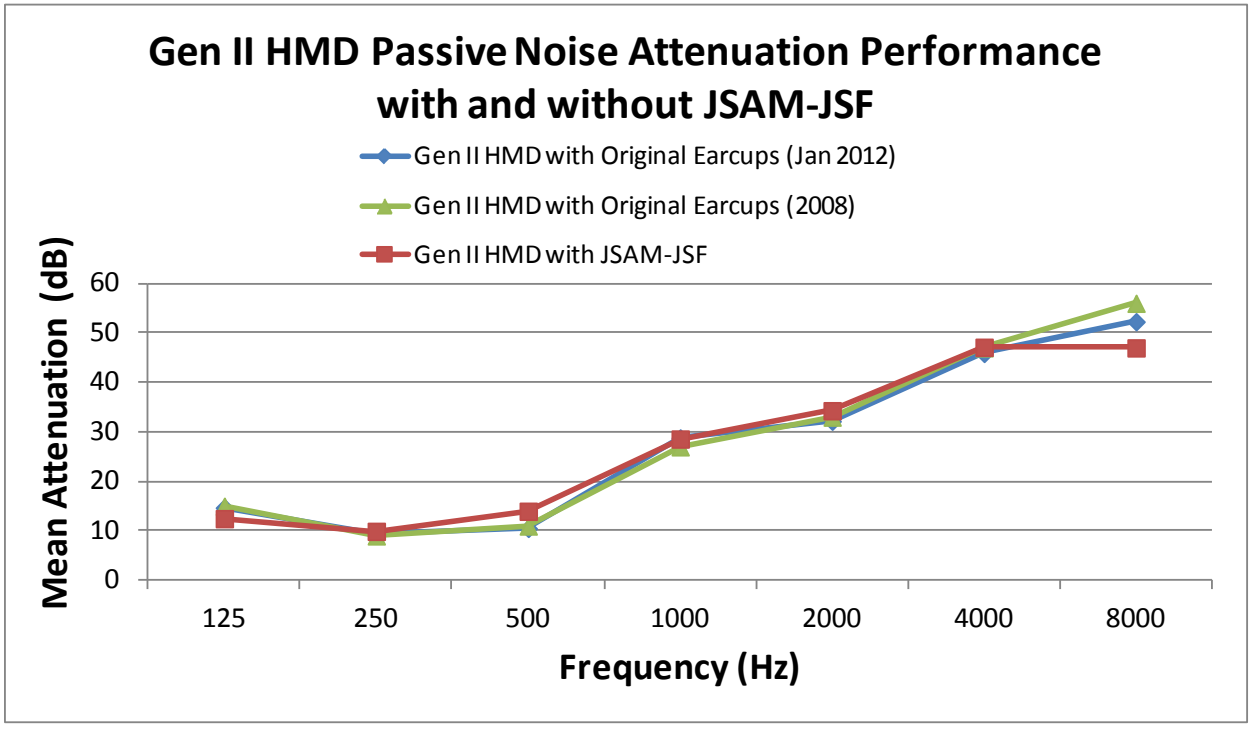


Figure 6. Mean passive attenuation results comparing the Gen II HMD with and without JSAM-JSF

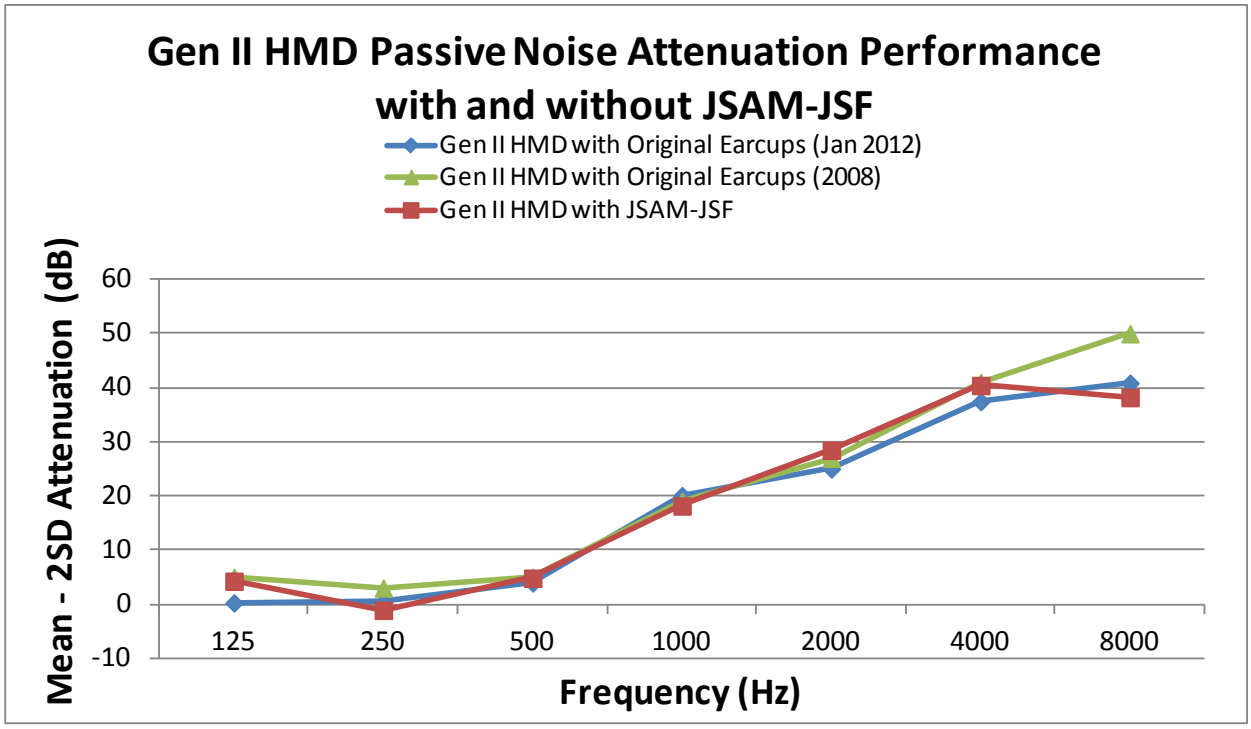


Figure 7. Mean minus 2 standard deviation passive attenuation results comparing the Gen II HMD with and without JSAM-JSF

4.2 MIRE – Active Insertion Loss

Active insertion loss measurements were collected in AFRL's MIRE facility on the JSAM-JSF worn in combination with the Gen II HMD. Mean data for all 10 subjects from 125 Hz to 8k Hz is shown numerically, Table 5, and graphically, Figure 8. Figure 8 compares the active insertion loss of the Gen II HMD with and without JSAM-JSF. A degradation of active insertion loss, as large as 10 dB, occurred at the lower frequencies with the addition of the JSAM-JSF to the Gen II HMD when compared to the Gen II HMD alone.

Table 5. Mean active insertion loss results from MIRE measurement

	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
Gen II HMD with Original Earcups (Jan 2012)	7.70	13.10	13.80	3.60	-2.10	-0.80	-0.20
Gen II HMD with Original Earcups (2008)	7.45	12.99	13.28	3.19	-2.25	-1.18	-0.03
Gen II HMD with JSAM-JSF	-0.07	2.81	5.35	0.15	-0.31	0.14	0.11

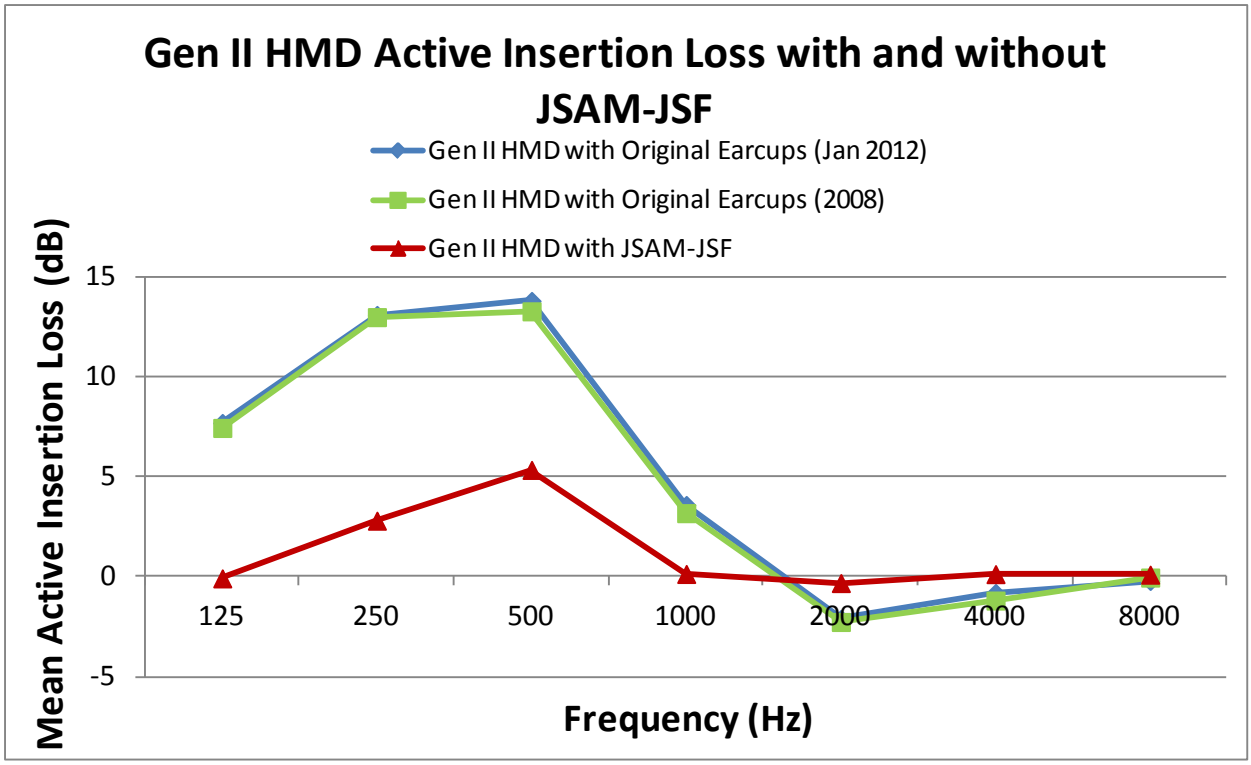


Figure 8. Active insertion loss results comparing the Gen II HMD with and without JSAM-JSF

4.3 Total Attenuation

Total attenuation performance for the JSAM-JSF worn in combination with the Gen II HMD was calculated by adding the mean minus 2 standard deviation passive attenuation data to the mean active insertion loss data across all seven frequencies. Total attenuation data is shown numerically, Table 6, and graphically, Figure 9. Figure 9 compares the total attenuation of the Gen II HMD with and without JSAM-JSF. Figure 10 compares the JSAM-JSF requirement (Gen II HMD total attenuation minus 3 dB across all frequencies, Table 1) to the total attenuation of the JSAM-JSF worn in combination with the Gen II HMD.

Table 6. Total attenuation results calculated from REAT and MIRE measurements

	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
Gen II HMD with Original Earcups (Jan 2012)	7.95	13.51	17.73	23.68	22.90	36.65	40.66
Gen II HMD with Original Earcups (2008)	12.45	15.99	18.28	22.19	24.75	39.82	49.97
Gen II HMD with JSAM-JSF	4.18	1.70	10.17	18.31	28.16	40.57	38.31

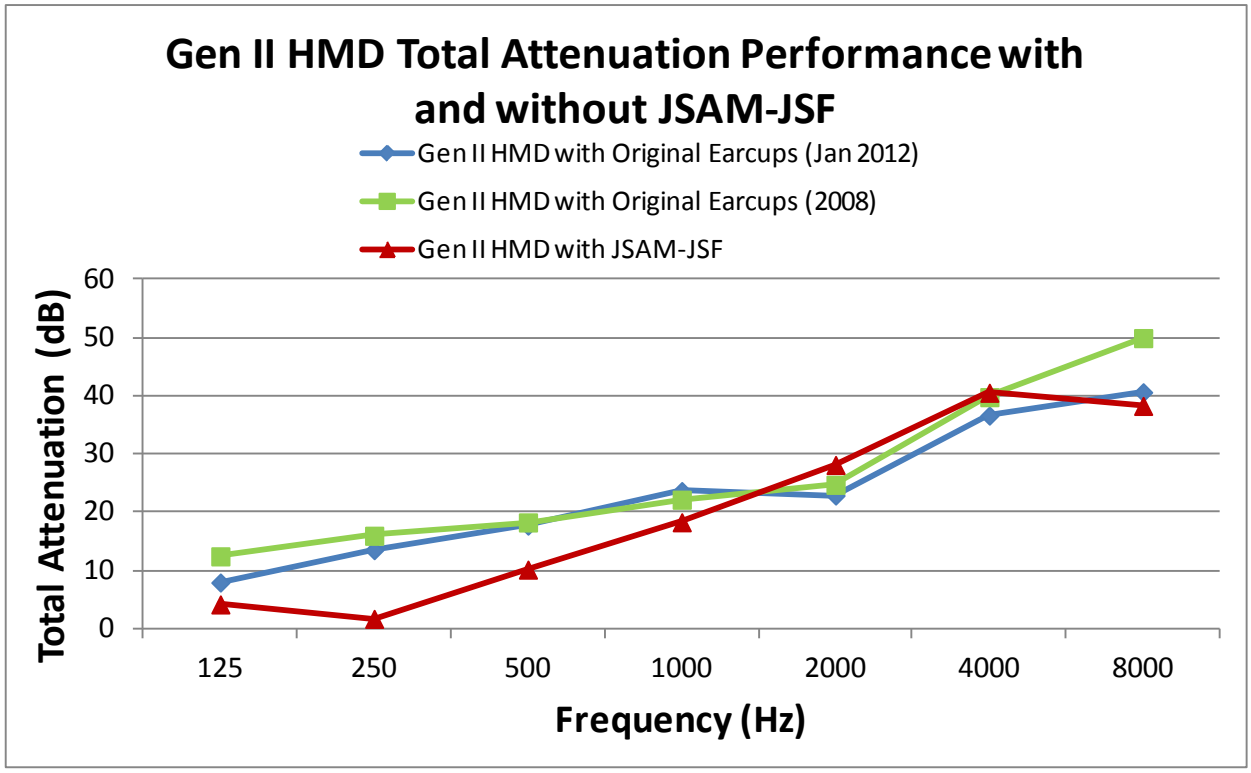


Figure 9. Total attenuation results comparing the Gen II HMD with and without JSAM-JSF

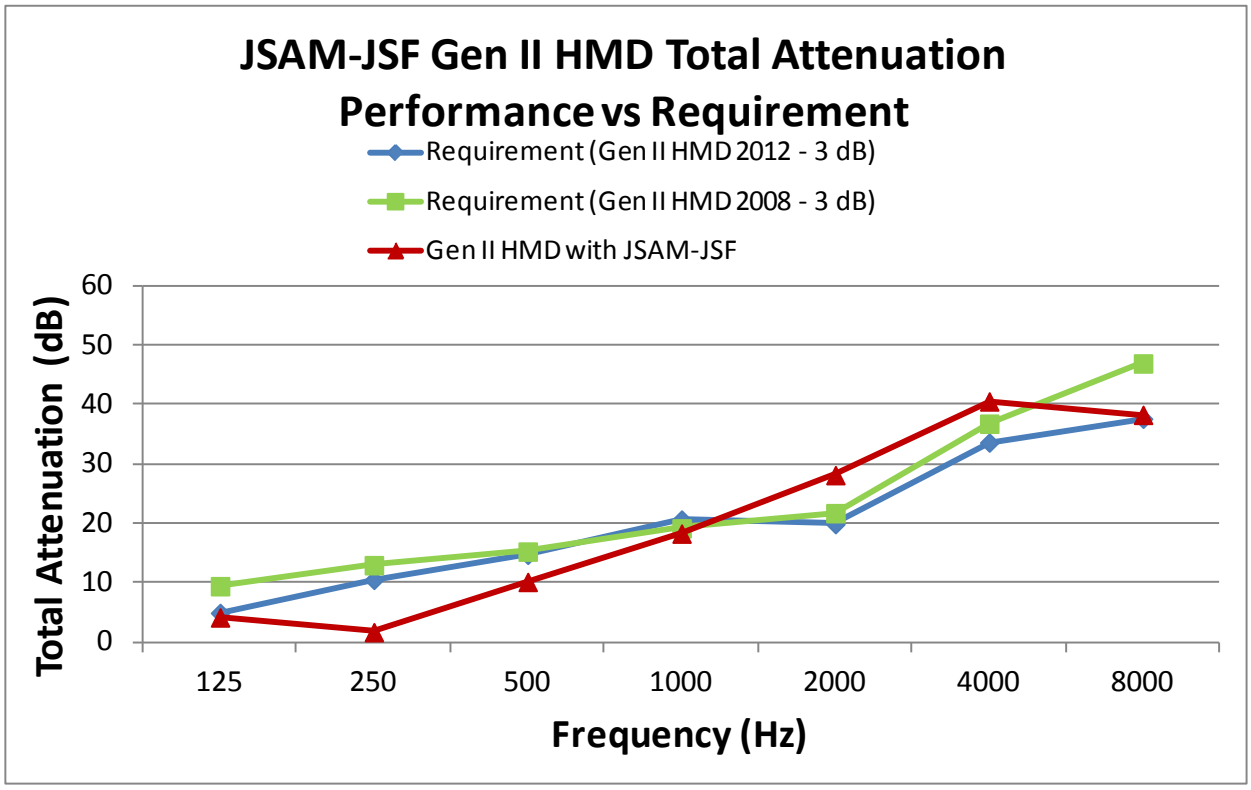


Figure 10. Total attenuation results comparing the JSAM-JSF worn in combination with the Gen II HMD and the JSAM-JSF requirement

5.0 DISCUSSION

Noise attenuation measurements were collected on the JSAM-JSF worn in combination with the Gen II HMD at AFRL. When comparing the passive attenuation of the Gen II HMD with and without the JSAM-JSF, small differences in mean attenuation and standard deviations were found across all frequencies. These differences could be attributed to the fit of the JSAM-JSF and/or the Gen II HMD, the expert fitters, different subjects, etc. The differences were not only seen when comparing the Gen II HMD with and without the JSAM-JSF, but also the attenuation results of the Gen II HMD alone when collected at different times (2008 and 2012).

When comparing the active insertion loss performance of the Gen II HMD alone for measurements collected in 2008 and 2012, almost no differences were found (0.5 dB or less across all frequencies). However, when comparing the Gen II HMD with and without the JSAM-JSF, differences as large as 10 dB were found in the lower frequencies. Consequently, when calculating the total attenuation and comparing the JSAM-JSF to the requirement (Gen II HMD total attenuation minus 3 dB per octave band), differences of 3 dB or greater were found in the lower frequencies (125-500 Hz).

The reduction in active insertion loss with the addition of the JSAM-JSF could potentially be improved by fully integrating the ANR earcups of the Gen II HMD into the JSAM-JSF design. This would eliminate the material under the earcup that adversely affects the active noise reduction capability. This integration would be a complete redesign of the respiratory hood and donning/doffing the hood and helmet may be troublesome. The addition of earplugs could also potentially improve attenuation, mostly in the upper frequencies, but aircrew acceptability and the aircrew's physical ability to wear earplugs would be an issue.

6.0 CONCLUSION

The JSAM-JSF is crucial in protecting the aircrew from respiratory hazards when flying in a CB warfare environment. In order to also protect the aircrew from noise induced hearing loss and to preserve proper communications when the JSAM-JSF is worn in combination with a hearing protector, no more than 3 dB of noise attenuation degradation is acceptable across all frequencies when compared to the hearing protector worn alone. When comparing the total attenuation of the Gen II HMD with and without the JSAM-JSF, a degradation of 3 dB or more was found at the lower frequencies (125-500 Hz) with the addition of the JSAM-JSF. This degradation was due to the reduction of active insertion loss. An integrated ANR earcup into the design of the JSAM-JSF could potentially alleviate the reduction in active insertion loss therefore improving the degradation in the lower frequencies allowing the JSAM-JSF to meet the requirement.

7.0 REFERENCES

1. ANSI S12.6-1997(R2002) American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors.
2. ANSI S12.42-1995(R2004) American National Standard for Microphone-in-real-ear and Acoustic Test Fixture Methods for the Measurement of Insertion Loss of Circumaural Hearing Protection Devices.
3. F-35 Lightning II Gen II HMD and JSAM Noise Attenuation Test Plan, March 1, 2012, Document No: 2ZCA12339, Lockheed Martin CAGE Code: 81755.
4. Whitaker, K. (2008) Joint Strike Fighter (JSF) Aerospace Equipment Instruction (AEI) Helmet Mounted Display (HMD) Donning/Doffing Procedure (Reference: 2ZUA05009, Rev. A). April 7, 2008.

8.0 LIST OF ABBREVIATIONS AND ACRONYMS

711 HPW/RHCB	711th Human Effectiveness Directorate, Decision Making Division, Battlespace Acoustics Branch
AFRL	Air Force Research Laboratory
ANR	Active Noise Reduction
ANSI	American National Standards Institute
CB	chemical/biological
Gen II	Generation II
HISL	Helmet Integrated System Ltd
HMD	Helmet Mounted Display
JSAM	Joint Service Aircrew Mask
JSF	Joint Strike Fighter
LM	Lockheed Martin
LPU	life preserver unit
MIRE	Microphone-in-Real-Ear
REAT	Real-Ear Attenuation Threshold
VSI	Vision Systems International